

to make more widely known the views of a man of science whose speculations were in advance of the age in which he lived.

In the *American Journal of Science* (vol. xix. p. 345) Mr. B. J. Harrington describes an investigation of a peculiar variety of foetid calcite found near the township of Chatham, in the Grenville region of Canada. The calcite, although nearly pure, when struck or scratched evolves a powerful and unpleasant odour, which is shown to be due to hydrogen sulphide occluded in the mineral in minute cavities, probably in the liquid state. The proportion of hydrogen sulphide is about 0.016 per cent. of the weight of the calcite. A striking property of this variety is that when heated to 160° C. it shows a strong, deep yellow phosphorescence, which persists during several minutes after its removal from the source of heat.

In part i. of vol. ix. of the *Transactions of the Royal Dublin Society*, Prof. J. A. McClelland continues the investigation which has already been mentioned in these notes (vol. lxxi. p. 543) of the relation between the atomic structure of substances and their power of giving rise to a secondary radiation under the influence of the β and γ rays of radium. It is shown that as the atomic weight increases the secondary radiation also increases, and that, as regards the latter, the elements may be arranged in a series of groups which correspond strictly with the periods of Mendeléeff's classification. The curve connecting atomic weight and the power of giving rise to a secondary radiation is of particular interest, as it throws light on the manner in which atoms are built up from electrons. It is important to note that the density of a substance has comparatively little influence on its power of producing secondary radiation.

THE catalogue of geological literature added to the Geological Society's library during the year ended on December 31, 1904, has just been issued. The catalogue is published by the Geological Society at the price of 2s.

THE index number of the *Psychological Review* for 1904 has just been published by the Macmillan Company of New York. The index is a very complete bibliography of the literature of psychology and cognate subjects for the year 1904, and has been compiled by Prof. Howard C. Warren, of Princeton University. It occupies no less than 240 pages, and contains 3445 entries of separate papers or volumes by psychologists of all nations.

OUR ASTRONOMICAL COLUMN.

A PROBABLE NOVA IN OPHIUCHUS.—From an examination of the Henry Draper memorial photographs in 1899, Mr. Fleming came to the conclusion that the star R.S. Ophiuchi was of the Nova type. Its spectrum, as shown on a plate taken on July 15, 1898, contained the hydrogen lines H ϵ , H δ , H γ , and H β , and the lines at $\lambda\lambda$ 4656 and 4691 as bright lines, thus resembling Novæ Sagittarii and Geminorum. A spectrum obtained on July 14, the preceding day, confirmed the presence of these bright lines, whereas one photographed on August 28, 1894, was simply of the K type without bright lines.

Miss Cannon recently examined the light curve of this star since 1888, and found that it varied considerably and rapidly about the time at which the bright line spectra were obtained. Thus on May 31, 1898, the magnitude was only 10.8, but a month later, on June 30, it had become 7.7, and it subsequently decreased, at the regular rate of about one magnitude per month, until on October 8 it was only 10.8 again. A minor recrudescence took place in 1900, followed by another decrease, and

since then the magnitude has remained faint at about 10.0, just as other Novæ, e.g. P Cygni, have, since the waning of their initial outbursts, remained fairly constant. An examination of several good chart plates revealed only a single star in the position occupied by this body. As many previous Novæ, having spectra similar to that of this star at its brightest, have been shown to have existed in the same positions prior to their discovery, Prof. Pickering contends that R.S. Ophiuchi should be classed as a Nova, when its proper designation would become Nova Ophiuchi No. 3, the new stars of 1604 and 1848 having appeared in the same constellation (Harvard College Observatory Circular, No. 99).

OBSERVATIONS OF PROMINENCES ON THE SUN'S LIMB.—In No. 5, vol. xxxiv., of the *Memorie della Società degli Spettroscopisti Italiani*, Prof. Mascari gives, for 1904, his usual annual summary of the observations of solar prominences made at the Catania Observatory. From the tables given we see that the prominence activity was augmented during 1904, also that the law that as the daily frequency of prominences increases their mean heliographic latitude decreases was confirmed; in 1902 the value was 48°.4, in 1903 it was 42°.1, but in 1904 it decreased to 36°.6. During the first quarter of last year the prominences occurred with a greater frequency in the southern hemisphere, but during the other three quarters the reverse was the case, the mean daily frequencies for the year being:—northern hemisphere 1.57, southern hemisphere 1.33.

A plate issued with the preceding number of the same journal shows, graphically, the positions and magnitudes of the prominences observed on the limb during the period March 14 to May 11, 1902, at the observatories of Catania, Kalocsa, Odessa, Rome, and Zurich. By thus combining the observations made at different places, it was possible to obtain a complete daily record for the whole period, with the exception of four days. Several outstanding disturbances are obvious, especially one extending from N. 42° W. to N. 84° W., and enduring as a limb disturbance from March 14 to 18.

DETERMINATION OF METEOR RADIANTS.—Commenting on a mathematical paper, on the determination of meteor radiants, recently read before the Royal Astronomical Society by Mr. Chapman, Mr. Denning issues a warning against the acceptance of any radiant, except in special circumstances, determined from the observations of less than five paths. The errors of observation, unless the observer has had much experience, are sufficient to overburden the catalogue of radiant points with a number of false radiants if three paths be accepted as sufficient data. When the altitude of the radiant is small, the meteors traverse long paths, and a consideration of three of these may give a satisfactory value, otherwise three is wholly insufficient. Mr. Denning advises meteor observers to keep a careful record of all faint showers suspected, and endeavour to corroborate them at the subsequent recurrences of the same epochs. By doing this and combining the results, well supported radiants may be established (*Monthly Notices of the Royal Astronomical Society*, April).

THE DEVELOPMENT OF SPECTRO-CHEMISTRY.¹

THE series of optical researches carried on by the late Dr. J. H. Gladstone, at first in collaboration with the Rev. T. Pelham Dale, established the important fact that Newton's expression for refraction, $(n^2 - 1)/d$, is not constant, but varies considerably with the temperature. On the other hand, it was found that the more simple ratio $(n - 1)/d$ remains practically constant.

Soon after 1860, Hans Landolt came forward with his optical researches. He began by confirming the results of Gladstone and Dale. He proceeded a step further, however, by following the example of Berthelot, and comparing the refractivity, not of equal, but of molecular

¹ Abridged from a discourse delivered at the Royal Institution on Friday, May 26, by Prof. J. W. Brühl.

quantities of the substances. If P represents the molecular weight, the product $[(n-1)/d]P$ is the *molecular refraction*.

Landolt examined particularly the fundamental question whether a different grouping of the same number of atoms of the same elements—which is the cause of isomerism—has any influence on the optical properties of bodies.

He established the important fact that only the relative weight of the elements is of influence on the molecular refraction of a compound, while the different grouping of the atoms has no appreciable effect; and this made it possible to determine the atomic refractions of the elements. The atomic refraction of carbon, for instance, was obtained by comparing the molecular refractions of two compounds which differed only by one atom of carbon; and in a similar manner the atomic refractions of the remaining elements were determined.

With the aid of these constants it was now possible to calculate *a priori* the molecular refraction of many organic compounds from the elements composing them, and Landolt showed that the calculated molecular refractions agreed very well with those determined by experiment.

Gladstone, in the course of his researches, was able to confirm Landolt's results in many cases. But he also found a considerable number of substances in which the observed molecular refraction was completely at variance with that obtained by adding the atomic refractions together. The exceptions were so numerous that they really seemed to overthrow the whole law of summation.

Shortly before 1880, when I was studying the literature of chemical optics, a brief note published by Gladstone in the *Journal of the Chemical Society* for May, 1870, excited my attention and curiosity. The author there discusses the exceptions to Landolt's rule of summation. He shows firstly that in all such cases the molecular refraction is never found to be too small, but always too great. Then he shows that whole classes of compounds behave in this abnormal fashion.

All optically abnormal compounds proved to be rich in carbon. Gladstone, therefore, examined the effect which a gradual increase of carbon in the composition of a body exerted on its refractivity. He found that there actually was an increase in the excess of the experimental as compared with the calculated molecular refraction, but the increase was not regular enough to explain the anomalies.

The saturated hydrocarbons, or *paraffins*, of the general composition C_nH_{2n+2} , showed *normal* molecular refraction. Also the *olefines*, containing two atoms less of hydrogen, were found normal by Gladstone. On the other hand, the hydrocarbons, containing six atoms less of hydrogen, viz. the *terpenes*, gave molecular refractions about 3 units larger than would correspond to their composition.

With the aromatic hydrocarbons, such as benzene, toluene, &c., containing eight atoms less of hydrogen, this abnormal excess amounted to 6 units:—

Paraffins	...	...	...	(C_nH_{2n+2})	Normal
Olefines	...	...	...	"	$-H_2$ "
Terpenes	...	...	...	"	$-H_6$ " +3
Benzene and derivatives	...	...	...	"	$-H_8$ " +6

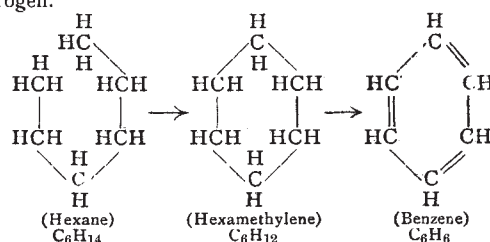
With still further decrease in the quantity of hydrogen contained (*i.e.* with further increase of carbon), there resulted greater and greater refractive increments. The last member of the series, however—pure carbon without any hydrogen, represented by the diamond—proved to be perfectly normal in its optical properties.

It seemed to me really extraordinarily remarkable that all optically abnormal substances, without exception, gave a too *high* molecular refraction. It was no less astonishing to me that the saturated hydrocarbons were optically normal, but became more and more abnormal at successive withdrawals of hydrogen—while pure carbon, uncombined with hydrogen, is again completely normal.

But I was most particularly struck by the quantitative amount of the abnormality in the case of benzene compounds, especially their refractive increment of *six* units. The number 6 fascinated me. I could not help thinking that therein lay the key to the mystery, and I lost no time in making use of it.

According to Kekulé's ingenious hypothesis we can imagine benzene, C_6H_6 , to have arisen from the saturated

hydrocarbon hexane, C_6H_{14} , by successive removal of hydrogen.



Thus altogether four pairs of hydrogen atoms have been removed. The elimination of the first pair was made the occasion to form another *simple* carbon bond, like those already present in hexane, and with it the ring was closed. The splitting-off of the other three pairs of hydrogen atoms, on the other hand, resulted in the formation of three *double* bonds of carbon atoms—a kind of bond which does not occur in the optically normal hexane.

Now Gladstone had found that benzene exhibits a refractive increment of 6 units. Reading this, I was struck in a moment by the thought: might not this abnormal refractive increment of benzene be due to its double carbon bonds, which are absent in the optically normal hexane? If this were so, I went on to reason, since *three* double bonds in benzene correspond to a refractive increment of 6 units, therefore *one* double bond must entail the increment of 2.

These ideas received no support whatever from the then known facts. For Gladstone had stated expressly that the olefines, *i.e.* open-chain hydrocarbons, containing *one* double carbon bond, were optically *normal*. However, I did not allow myself to be discouraged; and my expectations were confirmed by the very first experiment. The olefine examined not only proved to be optically abnormal, but gave the predicted refractive increment of 2 units, corresponding to the presence of *one* double carbon bond. Gladstone, therefore, as I had supposed, was mistaken in this case. Further experiments proved that not one of the olefines was optically normal. Without exception they gave the refractive increment of 2 units, one-third of that of benzene.

I next proceeded to examine the di-olefines—substances which contain *two* double carbon bonds. Here also, in conformity with expectation, a constant refractive increment was found, double as large as that of the olefines and two-thirds of that of benzene:—

Paraffins	...	...	...	(C_nH_{2n+2})	Normal
Olefines	...	...	...	"	$-H_2$ " +2
Diolefines	...	...	...	"	$-H_4$ " +4
Benzene compounds	...	...	...	"	$-H_8$ " +6

The dimensions of our subject this evening prevent the detailed demonstration of these important facts by experiment. I will only show you that the spectrum of a saturated hydrocarbon (a paraffin) is distinguishable at a glance from that of a substance containing double bonds.

On this screen we project the electric spectrum of metallic calcium. First we cause the rays of light to pass through a prism filled with paraffin oil. Then we exchange this prism for another, filled with a substance containing atoms linked by double bonds. (Experiment.)

In the second case you observe, first, a much greater deviation of the whole spectrum, *i.e.* greater *refraction*, and secondly, far wider intervals between the coloured lines of the spectrum, *i.e.* greater *dispersion*, which is usually correlative to the refraction.

Thus quantitative experimental confirmation was obtained for the view that abnormal refractive increments which increase with the diminution of hydrogen contained in the substances are caused by the presence of double carbon bonds.

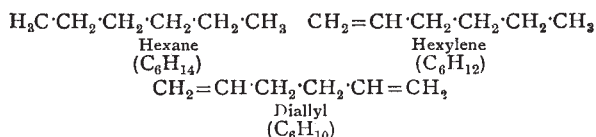
At the same time, however, the experiments yielded a second result of fundamental importance. The olefines contain 2, and the diolefines 4, atoms of hydrogen less than the paraffins. Similarly the refractive increment of the olefines is 2, and of the diolefines 4.

Benzene, C_6H_6 , contains 8 atoms of hydrogen less than the corresponding paraffin, hexane, C_6H_{14} . The increment of benzene, however, amounts not to 8, but to 6! Thus

in the formation of benzene from hexane, 2 atoms of hydrogen have been eliminated without influence on the refractive increment of the product.

But in the formation of benzene from hexane, 2 atoms of hydrogen have been employed to close the ring (see Fig. on p. 159). The withdrawal of these two atoms, and the closing of the ring, have therefore taken place without causing any optical anomaly.

In the formation of the olefines and diolefines from the paraffins, however, there is no closing of the ring. These substances are of open-chain structure, and every removal of 2 hydrogen atoms corresponds here to the creation of a double carbon bond:—



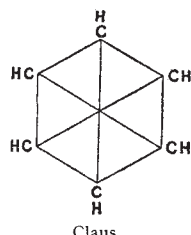
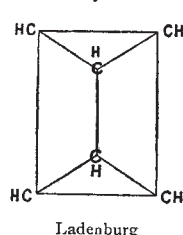
Hence, also, the refractive increment of the olefines and diolefines is directly proportional to the number of hydrogen atoms removed from the paraffin.

From all this it follows that the removal of hydrogen atoms causes optical anomalies only where double carbon bonds are created by the process. *The splitting-off of hydrogen which results in a closing of the ring is, on the other hand, without abnormal optical influence, and produces no refractive increment.*

This latter principle, which has since been confirmed many times by experiment, has proved of the same importance as the first in the investigation of the chemical structure of bodies.

A few examples will show how these two principles can be utilised for the discovery of chemical structure.

Besides the formula already mentioned for benzene—that suggested by Kekulé—several others have been proposed, e.g. those by Ladenburg and Claus:—

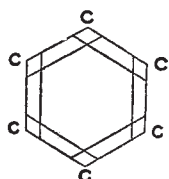


Neither of these graphic formulæ is reconcilable with the results of spectrochemical investigation, because the neighbouring carbon atoms contained in them are associated only by single, cycloid, or ring-closing affinities, and not by any so-called double bonds. Substances of this kind should be optically normal, while benzene and its derivatives are, as a matter of fact, abnormal. Kekulé's formula for benzene is really the only graphic representation of its structure in a single plane which is confirmed by chemical optics.

Thus it can be at once determined by optical methods whether a given body belongs to the paraffinoid, olefinoid, or cycloid products, whether these products contain double bonds or not, and, if so, how many.

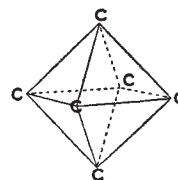
Now, too, we can imagine why the diamond, i.e. pure crystallised carbon, is, as already mentioned, optically normal. We obtain an idea of the chemical constitution of the mineral, and of the way in which the atoms of carbon are perhaps combined in the sparkling gem.

For the reasons already stated, the diamond cannot possibly contain any double bonds; a combination, say, in the form



with one atom of carbon at each of the six corners, and with each atom connected with its neighbour by a double bond, is altogether impossible.

Imagine, however, at each of the six corners of a regular octahedron, a single molecule of marsh-gas, CH_4 , i.e. altogether C_6H_{24} , and then imagine all the 24 hydrogen atoms successively removed, so that each carbon atom is connected with each of its neighbours only by a single bond, and thus all six atoms of carbon are united together in a single whole. Then you obtain, as the most simple representation of the molecule of the diamond, a regular octahedron, with one atom of carbon at each of its six corners, while the edges represent the mutual bonds:—



Several simple molecules of this kind may be combined into one crystallised particle of the spectrochemically normal diamond.

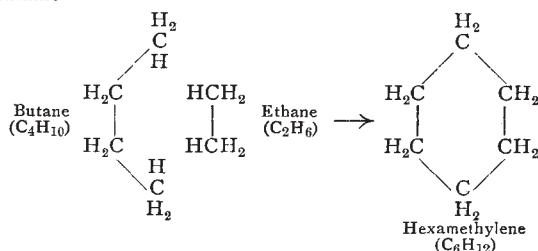
Thanks to the explanation of the optical behaviour of benzene, with the resultant discoveries, it all at once became possible to understand the causes of the spectrochemical abnormality of whole classes of bodies, such as the olefines, diolefines, terpenes, aromatic compounds, &c., and light was cast on the chemical constitution of whole classes of bodies.

At the same time, however, it at once became apparent why both Landolt and Gladstone had succeeded in observing complete optical normality in very numerous substances of the most various types—alcohols, acids, ethers, hydrocarbons, &c. And now it was understood why in such bodies the molecular refraction is determined solely by the component elements, while the different grouping of the atoms, i.e. the isomerism, remains without any appreciable optical influence.

All the bodies of this kind proved to be either paraffins, i.e. saturated hydrocarbons, or simple derivatives of the same. But the paraffins, as we now know, are always optically normal, because they contain no double carbon bonds. For this reason all such simple derivatives of the paraffins must also be normal. Their molecular refraction will thus always correspond to the elements of which they are composed, however the atoms may be grouped, i.e. chemical isomerism is here also without influence.

For the same reason, however, all cycloid (ring-shaped) closed formations, if they contain no double carbon bonds, must be optically normal, for those bodies also may be conceived as originating in the simple replacement of hydrogen by paraffin fragments, and may therefore be regarded as combined paraffins.

Thus we can imagine the hexamethylene already mentioned not only as formed from hexane by removal of two hydrogen atoms from the ends, but also as arising from ethane and butane, i.e. from two paraffins, by the removal of four hydrogen atoms and welding together of the remains:—



As a combined paraffin, hexamethylene must be normal, as is also confirmed by experiment, and here we see again, as in the case of the diamond, that a progressive removal of hydrogen and increase of carbon need not lead to the slightest optical anomaly.

At the same time there arises here a case of the optical influence of isomerism, for hexylene, which has already been mentioned, with the same formula (C_6H_{12}) as hexamethylene, but in structure an olefine:—



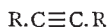
possesses the familiar refractive increment of 2 units. This example again shows how the spectrochemical behaviour of a body discloses its chemical structure by enabling us to distinguish with certainty between an optically normal cycloid (or ring-substance) and an isomeric open-chain olefinoid formation, which is optically abnormal.

Carbon can thus act variously upon light according to the manner in which its atoms are combined. We can therefore transfer the refractive increment of the double bond to the atom itself.

In the diamond, and in all paraffinoid carbon compounds, the atomic refraction of carbon equals 5: it is therefore equal to 10 for two carbon atoms. The double bond increases the refraction by 2, so that for two carbon atoms with a double bond the refraction amounts to 12. The atomic refraction of one carbon atom with a double bond is therefore equal to 6, i.e. 20 per cent. greater than that of the atom with the single bond:—

	Atomic Refraction
1 Carbon atom C (diamond and paraffins) ...	5
2 Carbon atoms 2C (diamond and paraffins) ...	10
Double bond	2
2 Carbon atoms with a double bond (C=C) ...	12
1 Carbon atom with a double bond (C=) ...	6

Carbon, being a quadrivalent element, can also appear with *triple* bonds:—



Experiment has shown that carbon with a triple bond also acquires a special atomic refraction.

Thus it becomes possible to establish the presence of this kind of bond in substances, and to distinguish it from the double and simple bonds—a further criterion of structure.

In consequence of these discoveries it became highly probable that all multivalent elements, such as carbon, possessed an atomic refraction varying with the kind of bond, while the univalent elements, such as hydrogen, display constant optic values because atoms such as theirs can only be linked with a simple bond.

Later researches have confirmed this. The univalent halogens give, like hydrogen, constant atomic refractions, both in the elementary state and in their compounds. The multivalent elements, on the other hand, such as oxygen and nitrogen, display different optical values, according to the kind of bond.

In the course of such researches the behaviour of oxygen as a quadrivalent element, which had been previously conjectured, was established with certainty, and afterwards confirmed synthetically by Collie, Tickle, and others.

The theory which accounted for the optical abnormalities of certain classes of bodies, making them, in fact, abnormalities no longer, has proved extraordinarily fruitful. It formed the starting point of all subsequent discoveries in the subject, and, indeed, we may describe the progress of this branch of science during the last twenty-five years as based essentially on this conception.

For not until we had fathomed the mystery of the benzene refractive increment 6 was it possible to know for certain that the variable valency of the multivalent elements is always of determining influence on the optical behaviour of bodies. Thus for the first time a spectrochemical method was called into being for the study of chemical structure, and the foundations were laid of what we now call "spectrochemistry."

We must now return once more to the formula for refractivity. Newton's expression $[(n^2-1)/d]P$ had proved not constant for the temperature in the case of fluid bodies, and was, therefore, replaced by Gladstone and Dale's more satisfactory ratio $[(n-1)/d]P$. For twenty years and more this did admirable service. As, however, the number

of observations kept on increasing, even this formula betrayed imperfections which finally led to its abandonment. It is impossible here to follow the argument in detail, and we must be content with the remark that comparisons of bodies in different states of aggregation failed to yield satisfactory constants. The values of $[(n-1)/d]P$ for a fluid or solid substance always came out considerably greater than for the same substance in the state of gas or vapour.

Then by a happy chance two physicists, L. Lorenz, of Copenhagen, and H. A. Lorentz, of Leyden, came forward simultaneously in 1880 with a new expression for refraction. One of them started from the ordinary theory of light, the other from Maxwell's electromagnetic theory of light based on Faraday's views, and they both reached the same result, viz. that the true measure of refractivity is furnished by the expression

$$\left(\frac{n^2-1}{n^2+2}\right)\frac{P}{d}$$

Experimental tests showed that this theoretical expression was, in fact, for all bodies, practically unaffected not only by temperature and pressure, but also by the state of aggregation.

Chemical tests confirmed the utility of the new optical standard, since the operation of all the laws before mentioned was observed to be even more exact when the new constant was applied.

Moreover, the expression for refraction proved valuable in another respect. It was found to be very suitable for measuring the *dispersive* power of bodies.

If n_v and n_r denote the refractive indices for the limits of the visible spectrum, i.e. for violet and for red light, the difference of the refractivities for these end-rays of the spectrum,

$$\left(\frac{n_v^2-1}{n_v^2+2} - \frac{n_r^2-1}{n_r^2+2}\right)\frac{P}{d}$$

is the measure of the power of different bodies to *disperse* light—to broaden out the spectrum. This ratio proved to be constant as regards temperature, pressure, and state of aggregation.

Gladstone had already observed that dispersion, like refraction, was connected with the chemical nature of bodies. Quantitative relations were, however, only obtained when a constant for refractivity had been found. And then from the molecular dispersions of compounds the atomic dispersions of their elements were deduced.

We cannot enter here into the relations which were thus shown to exist between the chemical composition of substances and their power to disperse light. We need only remark that the case as a whole is analogous to that of refraction. Dispersion is, however, a still more sensitive and more constitutional property, and therefore in many cases it is specially adapted as an aid to research on chemical structure.

It only remains to add a few remarks on the applications of spectrochemistry in science and in practical life.

It has already been shown the principles on which spectrochemical methods of examination in general can be applied to the solution of scientific problems, to the discovery of the chemical structure of single substances or whole classes of bodies.

Now there is a large number of substances, some of them artificially built up by synthesis out of their elements, some of them occurring in the vegetable and animal kingdoms, or even in inorganic nature, the structure of which is of remarkable delicacy and instability. Among them are, for instance, the so-called "tautomeric" compounds, hydrogen peroxide, and many other unstable compounds. Substances of this kind are of a very special interest, for in consequence of their tendency to change, they are the principal cause of metamorphoses, the unceasing circulation of matter, the eternal birth and decay that go on in nature.

Research in the atomic structure of such bodies by purely chemical methods is often very difficult, and not seldom impossible, because, owing to their sensitive organisation, chemical interference leads either to changes in the grouping of the atoms, which cannot always be controlled, or even to total decomposition.

In such cases it is of course of the greatest value to be able to examine the constitution of the bodies without affecting them chemically; and spectrochemistry, as we have seen, gives us the means of doing so. By observing the behaviour of light on its passage through the various substances, we gain an insight into their structure without in any way disturbing it.

In the last ten years the spectrochemistry of the nitrogen compounds has also made remarkable progress. Nitrogen is of the greatest importance as an essential constituent of the proteids, the alkaloids, and many other animal and vegetable products. But its high valency and the extraordinary variety of combinations into which it can enter with other elements surround it with special complications. Regardless of these, however, the spectrochemical examination of nitrogen compounds has already yielded useful results, especially in the study of the alkaloids. It is to be expected that this optical method will also be of use in the chemistry of the albuminoids, the study of which is now being prosecuted with so much vigour.

One class of substances of increasing importance both to science and to chemical industry is that constituted by the natural and artificial perfumes. An overwhelming majority of them consist of derivatives of the terpenes. We have already mentioned that Gladstone, in this subject also a pioneer, was the first to study the optical behaviour of the terpenes. Since then the explanation of the structure of these bodies and of a large number of rich natural perfumes derivable therefrom has been rendered easier by the use of spectrochemical methods. Similar assistance has been rendered to the synthetic preparation of valuable scents, such as ionone, the artificial scent of violets. In every scientific laboratory and in every rationally conducted chemical factory where work is being done on perfumes, the spectrometer is now an indispensable testing instrument, and hence also an implement in industrial production.

When scientific research opens up new methods of observing nature, it is generally not long before a use is found for these methods in practical life. The need is soon felt of perfecting, and at the same time simplifying, the scientific apparatus. Efforts in this direction have not been wanting in the case of the spectrometer, and they have been crowned with the most brilliant success.

Prof. Abbe, the distinguished physicist who died not long ago, and after him Dr. Pulfrich, constructed spectrometers on the principle of total reflection. These instruments are distinguished from those formerly in use by their extraordinary simplicity and convenience, and they allow also of much more rapid work.

Such instruments, known as total reflectometers, have been made for the most exact scientific measurements, and also for medical and technical purposes. Special forms are in use for the examination of fats and oils, milk and butter; to determine the amount of salt contained in salt solutions; the amount of alcohol and extractive matter in beer; for the examination of blood and albuminoids in pathological fluids, &c. Several of these ingeniously contrived instruments give not only the refractive index and the dispersion of a substance immediately, without any calculation, but also directly the percentage of dissolved matter, e.g. of alcohol and extractives in beer.

THE MIOCENE FORMATION OF MARYLAND.

WE have received from the Maryland Geological Survey a memoir on the Miocene formation of the State, in two volumes, text and plates. This is the second of a series of reports dealing with the systematic geology and palæontology of Maryland, that on the Eocene having been previously published, while reports on other formations are in progress. We may heartily congratulate the State geologist, Dr. Wm. Bullock Clark, on the appearance of these volumes, which in type and illustrations leave nothing to be desired, while the subject-matter, the result of labours extending over fifteen years, represents the combined work of field geologists and of experts in various branches of palæontology.

Of special interest is a chapter by Mr. W. H. Dall on the relations of the Miocene of Maryland to that of other

regions and to the recent fauna. He points out that the differentiation of faunas in European and North American areas was well established before the beginning of the Tertiary, so that in the early stages of that epoch the faunas in the west show American characteristics clearly as compared with those of Europe. Other differences, suggesting migrations, occur in the relative time of appearance of certain groups; as, for instance, in America, the first influx of Nummulites is in the upper beds of the lower Oligocene, just as these lowly forms of life were about to disappear from the European fauna, where they had long flourished. In the history of the American Miocene there are many differences and many points of agreement with European equivalents, which are duly pointed out. As in Europe, the Miocene was a period of elevation, of plication of the earth's crust, of denudation, and of the deposition over extended areas of sediment, chiefly of clays, sands, and marls, more or less consolidated. Diatomaceous deposits also occur.

In an introduction Dr. Clark discusses the general stratigraphic relations of the Miocene deposits of Maryland, which have long been known for the rich faunas which they contain. The Oligocene is not represented, and the strata lie unconformably on the Eocene. The palæontological relations, the subdivisions and geographical distribution of the strata are dealt with by Mr. G. B. Shattuck, who gives an elaborate table showing the localities and horizons of the species. The bulk of the volume is taken up with the systematic palæontology, the results of an exhaustive study of the fauna, embracing both a critical review of the species described by previous authors, as well as descriptions of a large number of new forms. As remarked by Dr. Clark, the description of species of fossils is of little scientific importance to the geologist, unless the object is something more than the mere multiplication of new forms. In the present case the endeavour has been made to clear up doubtful points in synonymy and to give as complete an account as possible of the geological and geographical ranges of the fossils. All groups from the Mammalia to the Radiolaria, Foraminifera and plants come under notice. The higher vertebrates are dealt with by Dr. E. C. Case, the fishes by the late Dr. C. R. Eastman, many of the invertebrates by Dr. G. C. Martin, the Echinodermata by Dr. Clark, and the remaining groups by other authorities.

The palæontology is illustrated by 135 plates, while in the volume of text there are sections, numerous pictorial views, and a coloured geological map. The work is well indexed, and there is a useful geological bibliography.

MINERAL PRODUCTION OF INDIA.

AN interesting new departure has been made by the Geological Survey of India in devoting the last issue of the *Records* (vol. xxxii., part i.) to a review of the mineral production of India during the years 1898 to 1903, by Mr. T. H. Holland, F.R.S., director of the Survey. This review, which covers 118 pages, with 6 plates, compares very favourably with the statistics of many countries where the facilities of obtaining information regarding the mineral production are far greater than in India. The period covered is six years, and it is intended in future to issue quinquennial reviews. The minerals are divided into two groups:—(1) those for which fairly trustworthy returns are available, and (2) those for which definitely recurring particulars cannot be procured. It is curious to note that in the review of mineral production in India issued by Sir George Watt in 1894, four minerals, salt, coal, iron ore, and petroleum, were the only representatives of the first group, whereas it is now possible to obtain trustworthy returns of the production of thirteen minerals, coal, gold, graphite, iron ore, jadeite, magnesite, manganese ore, mica, petroleum, rubies, salt, saltpetre, and tin.

The production of salt, which was 358,000 tons in 1898 and 336,000 tons in 1903, showed considerable fluctuations during the period under review; but in the case of all other minerals there was substantial progress. The Indian coal output rose from 4,000,000 tons in 1897 to 7,500,000 tons in 1903. The production of gold steadily increased from 390,502 ounces to 603,218 ounces. The production of saltpetre also increased, the average